REPORT DOCUMENTATION PAGE

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MEMORANDUM FOR PRS

FROM: PROI (TI) (STINFO)   4 June 1999

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-FY99-0120**
     D. T. Baron, "Fracture Parameter Calculations for SENT Specimens with Two Boundary Conditions"

SEM Presentation   **(Statement A)**

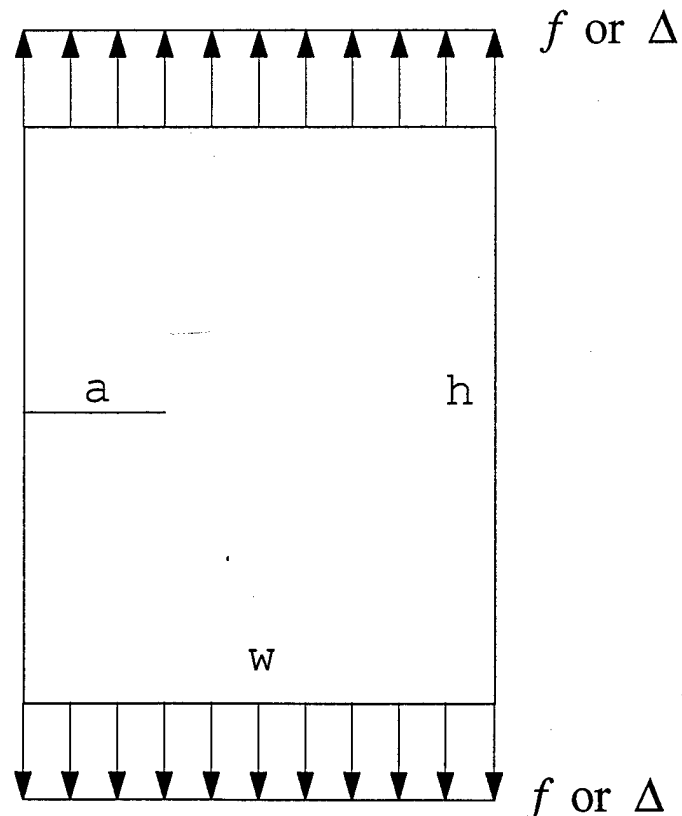# Fracture Parameter Calculations for SENT Specimens with Two Boundary Conditions

D.T. Baron
ERC Inc.
AFRL
Edwards AFB, CA

Single edge-notch tension (SENT) specimen, strained by applied uniaxial uniform load, or by applied uniaxial uniform displacement.

Finite element calculations of the stress intensity factors (K_1) and the T-stresses (T) for SENT specimens.

Four combinations of plane state and loading are used.

  plane stress with applied uniform load.

  plane stress with applied uniform displacement.

  plane strain with applied uniform load.

  plane strain with applied uniform displacement.

  Eleven specimen aspect ratios (h/w) are used.

  Nine specimen crack ratios (a/w) are used.

Material properties.

$E = 1096$

$v = 0.499, \quad \Rightarrow$ incompressible.

Geometries used for
SENT specimens.

$$\frac{h}{w} = \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, \frac{1}{1}, \frac{2}{1}, \frac{3}{1}, \frac{4}{1}, \frac{5}{1}, \frac{6}{1}, \frac{7}{1}, \frac{8}{1}$$

$$\frac{a}{w} = 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8$$

$\Rightarrow$ 99 different FEM meshes.

Methods of mesh strain application.

applied uniform displacement, $\varepsilon_{\infty} = 0.05$.

applied uniform load, $\sigma_{\infty} = 54.8$.

2D elasticity states.

plane stress.
plane strain.

ABAQUS version 5.6 finite element code.

J-integral calculated by the energy domain integral method.

Calculation of the stress intensity factor.

$$K_1 = \sqrt{JE'}$$

plane stress, $E' = E$

plane strain, $E' = E/(1 - v^2)$

Method of T-stress calculation.

Near the crack tip,

$$\sigma_{xx} \cong \frac{K_1}{\sqrt{2\pi r}} \cos\frac{\theta}{2}\left[1 - \sin\frac{\theta}{2}\sin\frac{3\theta}{2}\right] + T.$$

$\Rightarrow$ along the crack flank $(\theta = \pi)$,

$$\sigma_{xx} \cong T.$$

$$T \cong \sigma_{xx} = E' \varepsilon_{xx} = E' \frac{du_x}{dx}.$$

A least squares line was fitted to the FEM points (x, u_x) along the crack flank, within a distance of $a/10$ of the crack tip. (The distance $a/10$ was chosen arbitrarily.) The curve fit has the form

$$y = a + bx.$$

$$\Rightarrow \frac{du_x}{dx} \cong b, \quad \therefore T \cong E'b.$$

$$\beta \equiv \frac{T\sqrt{\pi a}}{K_1}$$

(A definition that is used later.)

Correlations of points (x, u_x) within $a/10$ of the crack tip.

(Each is average for 99 meshes.)	PLANE STRESS	PLANE STRAIN
APPLIED UNIFORM LOAD	+0.990	+0.993
APPLIED UNIFORM DISPLACEMENT	-0.999	-0.983

TYPICAL FINITE ELEMENT MESH
(SHOWING ORBITS 1-64.)

16 ELEMENT SECTORS
OF APPROX. EQUAL ANGLE.
8 SECTORS IN QUADRANT 1.
8 SECTORS IN QUADRANT 2.

64 ELEMENT ORBITS.
ORBIT CURVE GROWTH IS LINEAR
ALONG THE 3 AXIS HALF-LINES.

16.* 64 = 1024 ELEMENTS.

(TOP EDGE CONSTRAINED IN X DIRECTION.)

Y

x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x x

8 NODE
ISOPARAMETRIC
ELEMENTS.

h/2

X

y y y y y y y y y y y y y y y y y y y y y y y y y y y y y y y y

(BOTTOM EDGE AHEAD OF CRACK TIP
CONSTRAINED IN Y DIRECTION.)

a

w - a
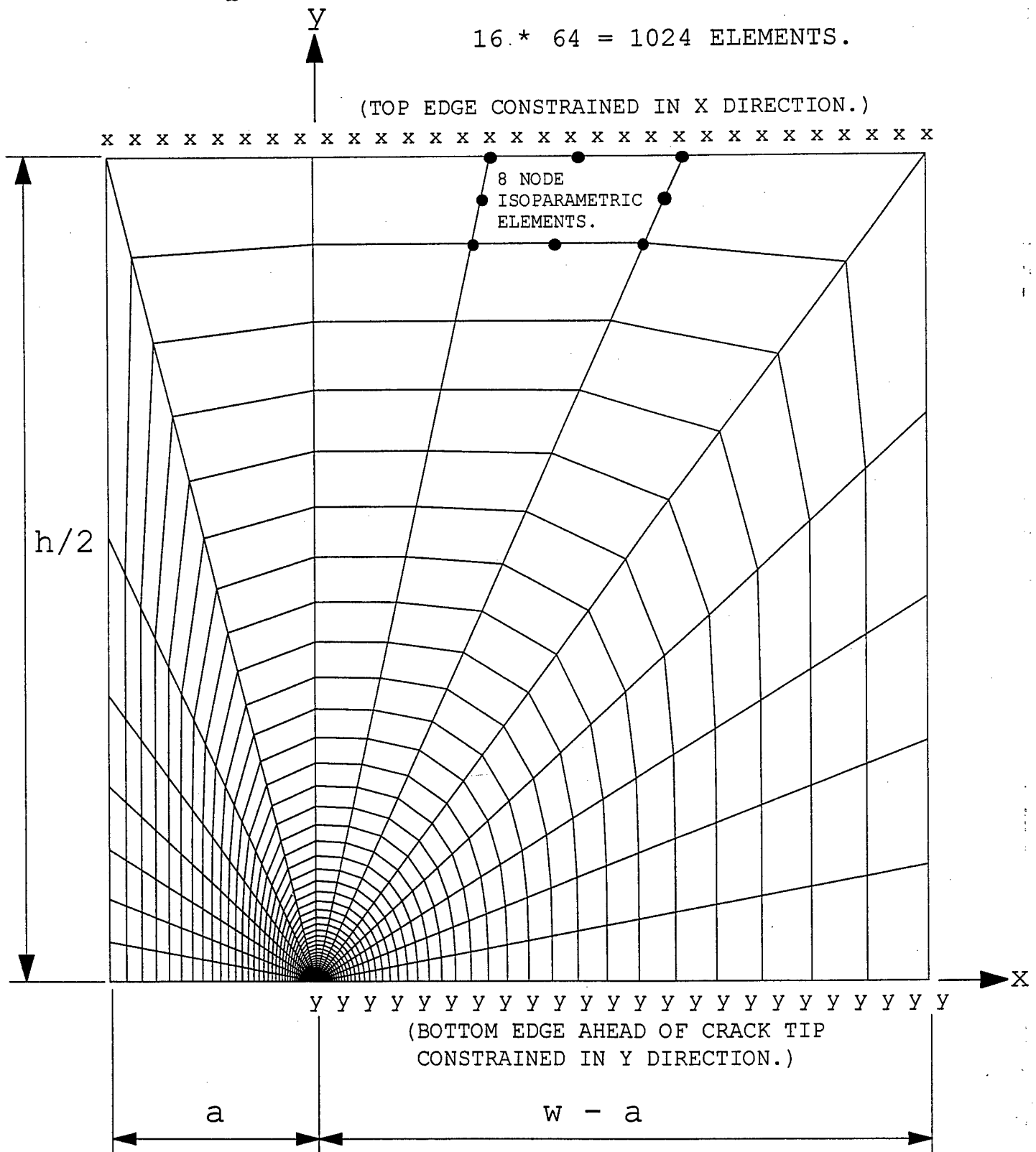
SAME FINITE ELEMENT MESH
(SHOWING ORBITS 33-64.)
(ORBITS 1-32 REMOVED.)
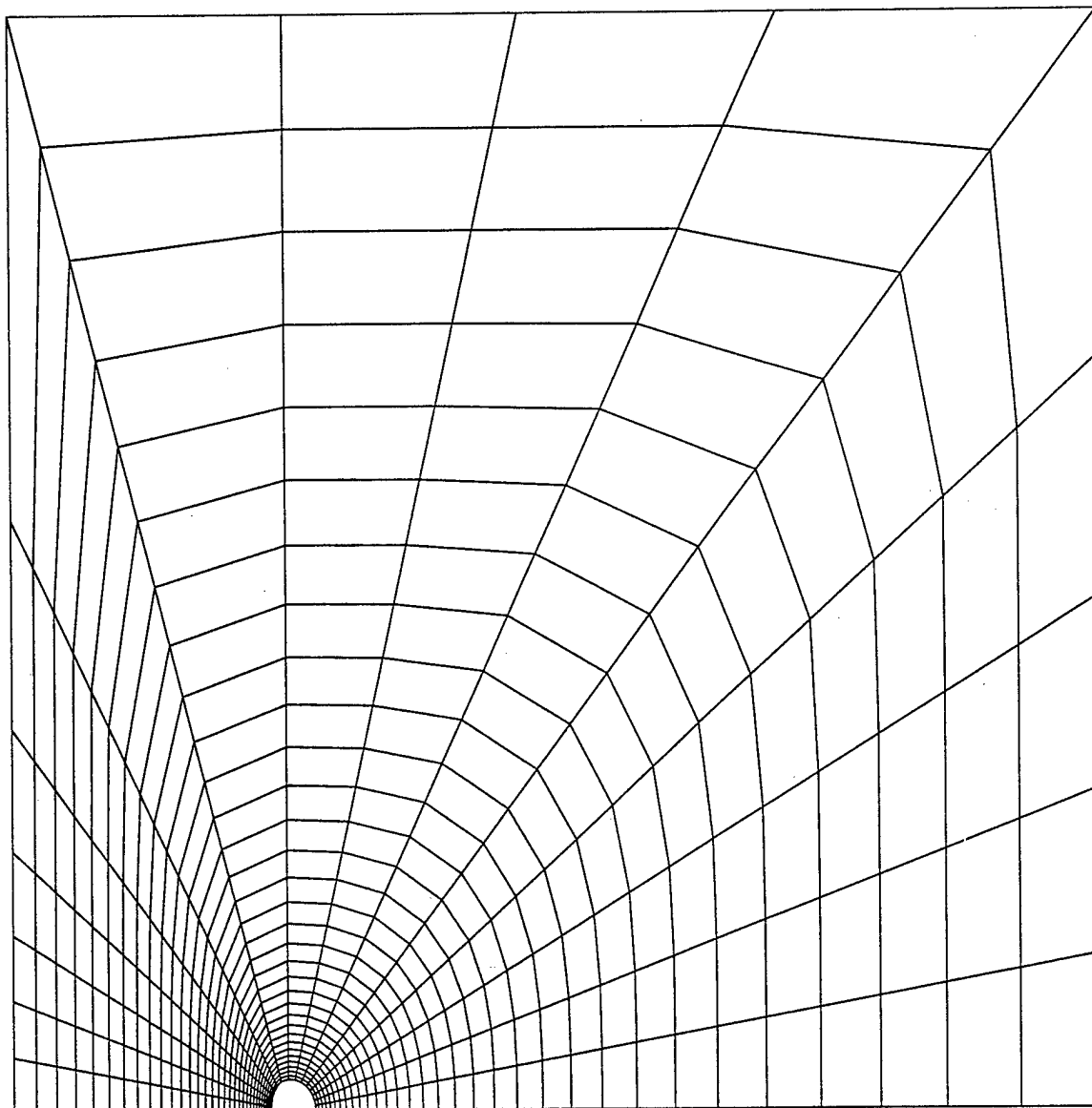
SAME FINITE ELEMENT MESH
(SHOWING ORBITS 1-32.)
(ORBITS 33-64 REMOVED.)
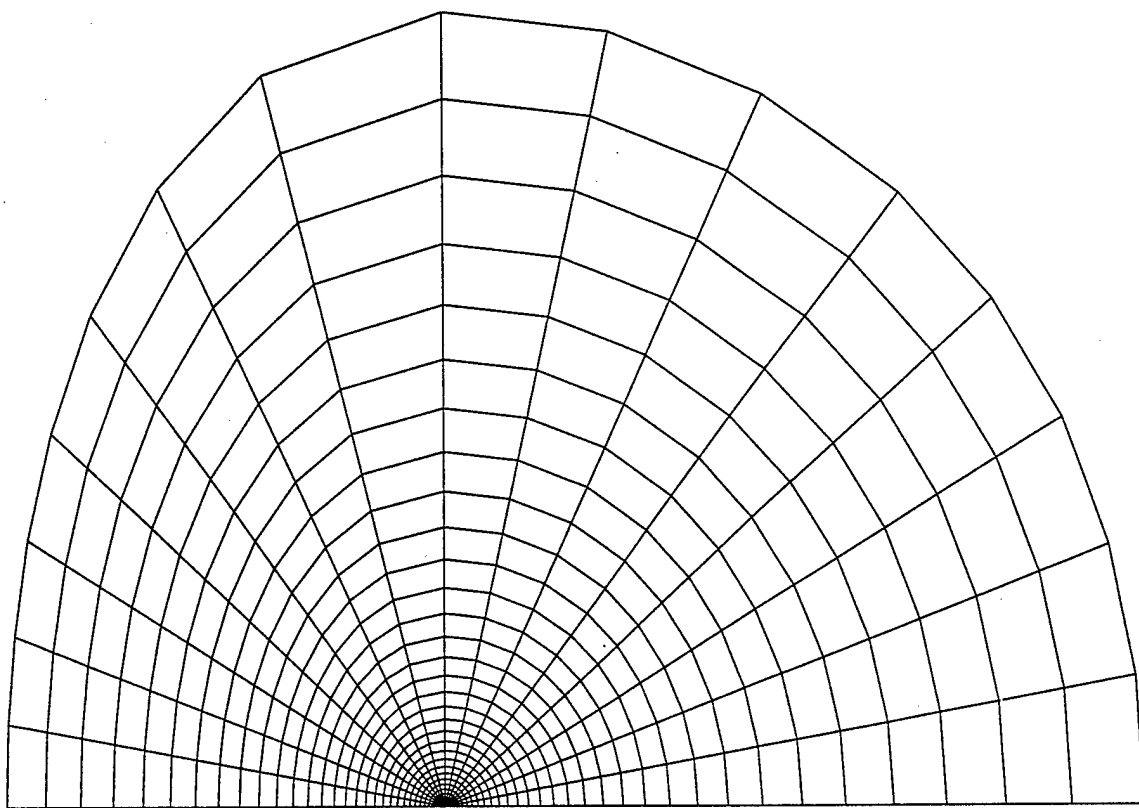
SAME FINITE ELEMENT MESH
(SHOWING ORBITS 17-32.)
(ORBITS 1-16 REMOVED.)
(ORBITS 33-64 REMOVED.)
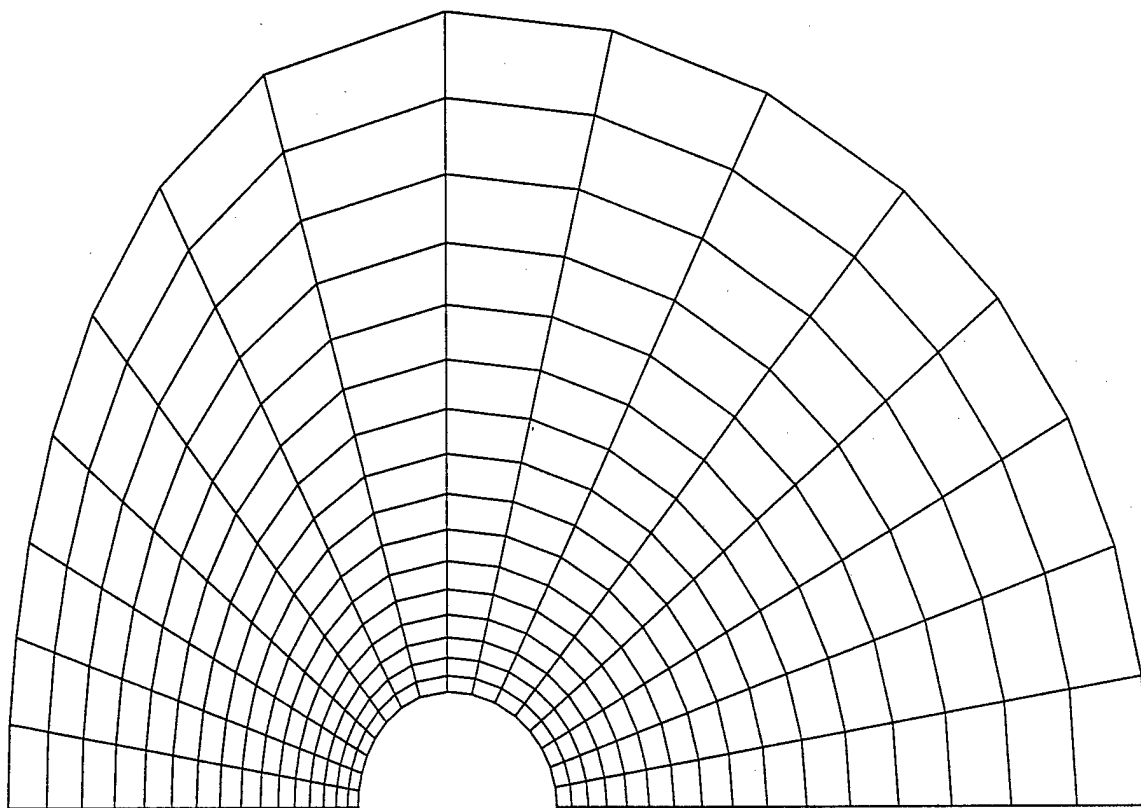
SAME FINITE ELEMENT MESH
(SHOWING ORBITS 1-16.)
(ORBITS 17-64 REMOVED.)
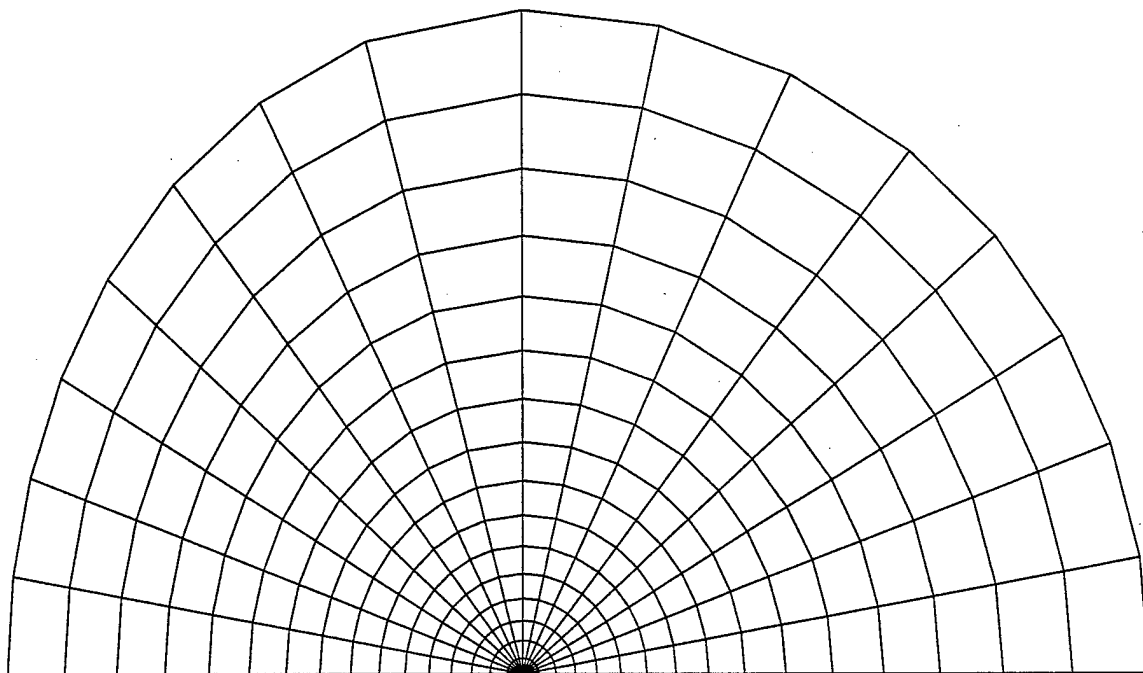
SAME FINITE ELEMENT MESH
(SHOWING ORBITS 9-16.)
(ORBITS 1-8 REMOVED.)
(ORBITS 17-64 REMOVED.)
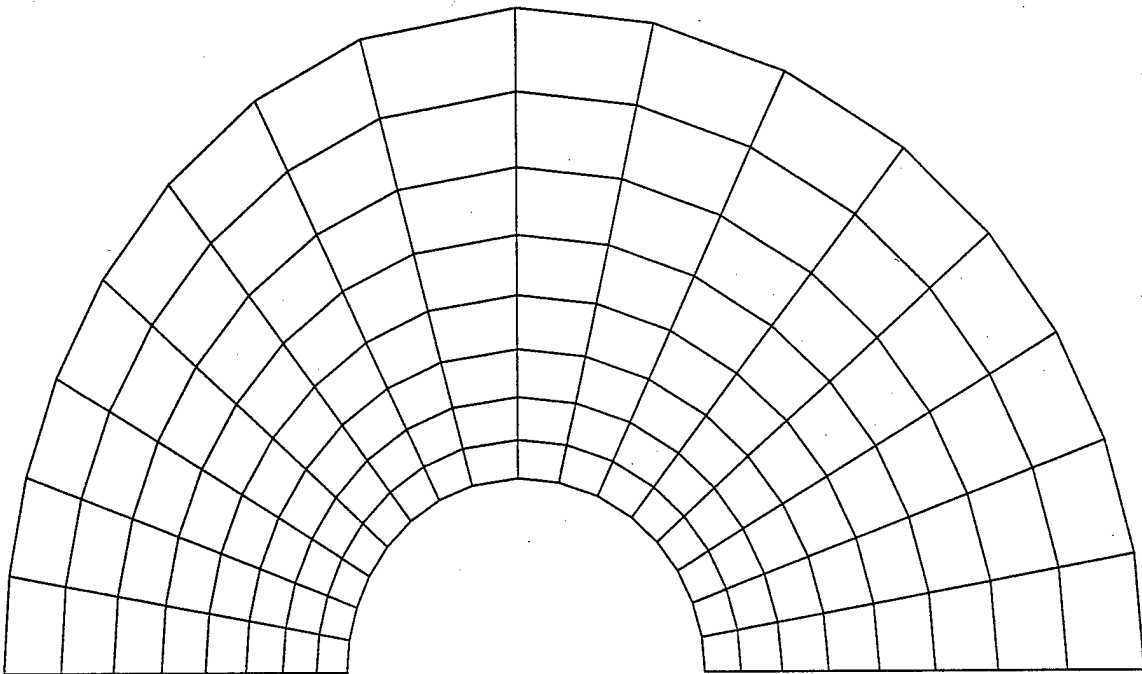
SAME FINITE ELEMENT MESH
(SHOWING ORBITS 1-8.)
(ORBITS 9-64 REMOVED.)
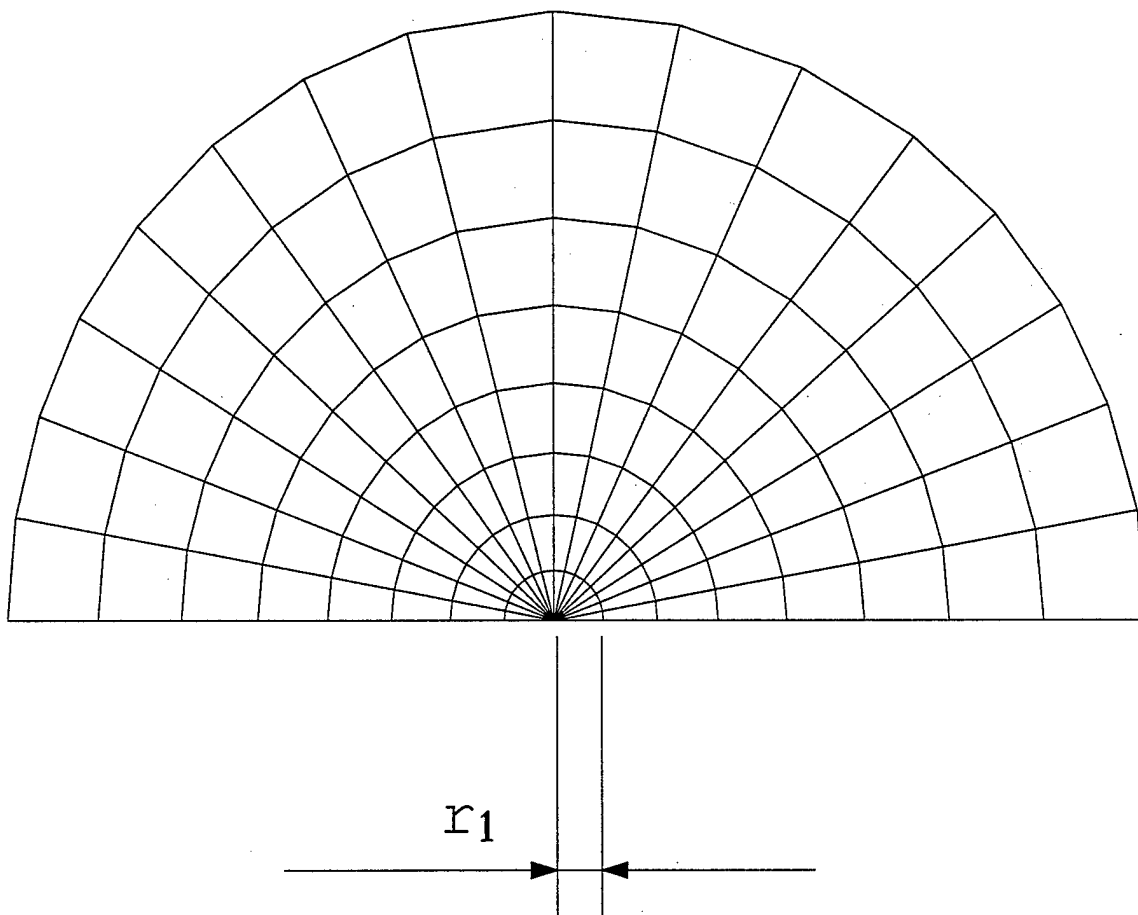
ORBIT CURVE 1 IS CIRCULAR, ALWAYS.
$r_1 = w / 10000$, ALWAYS.
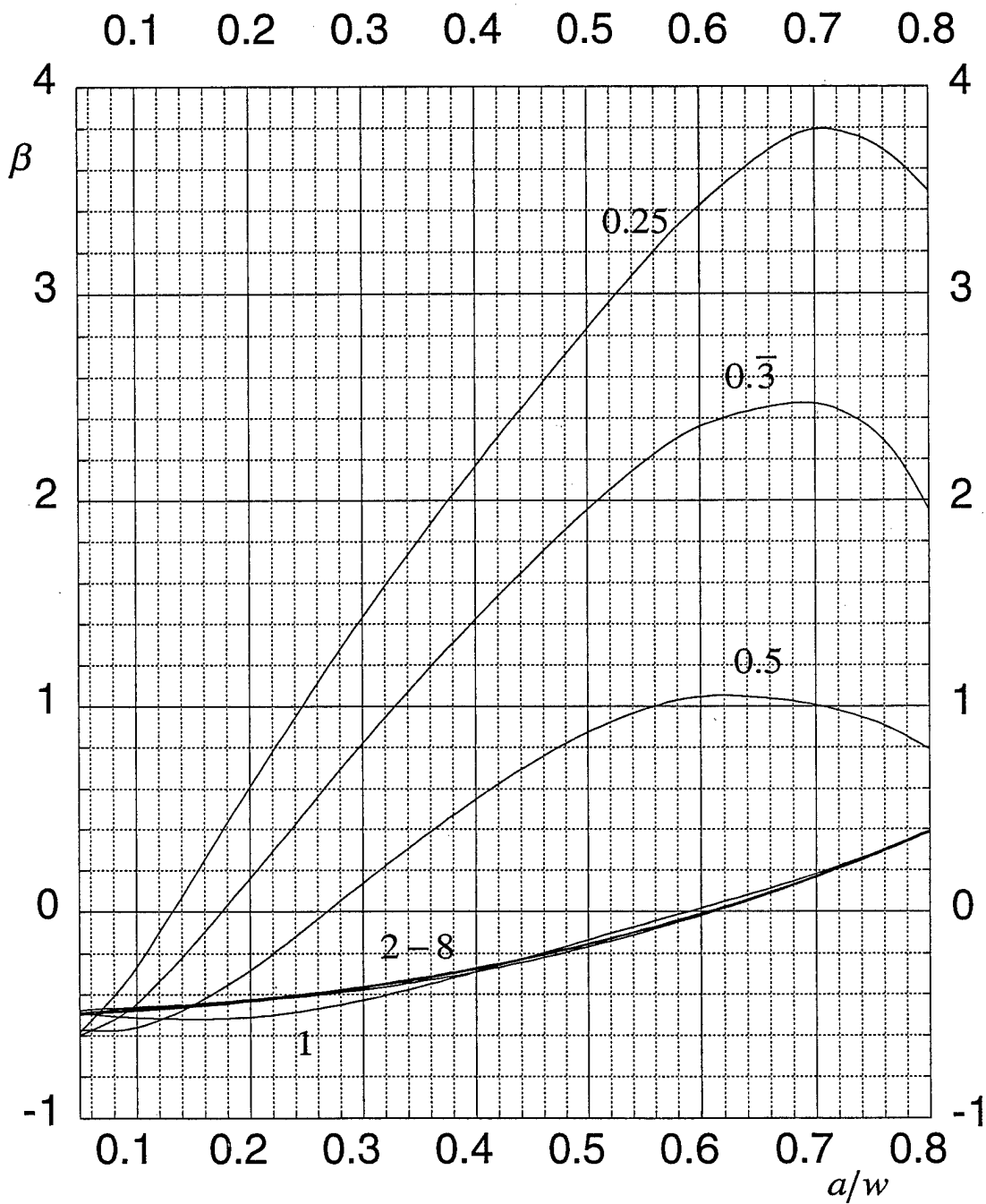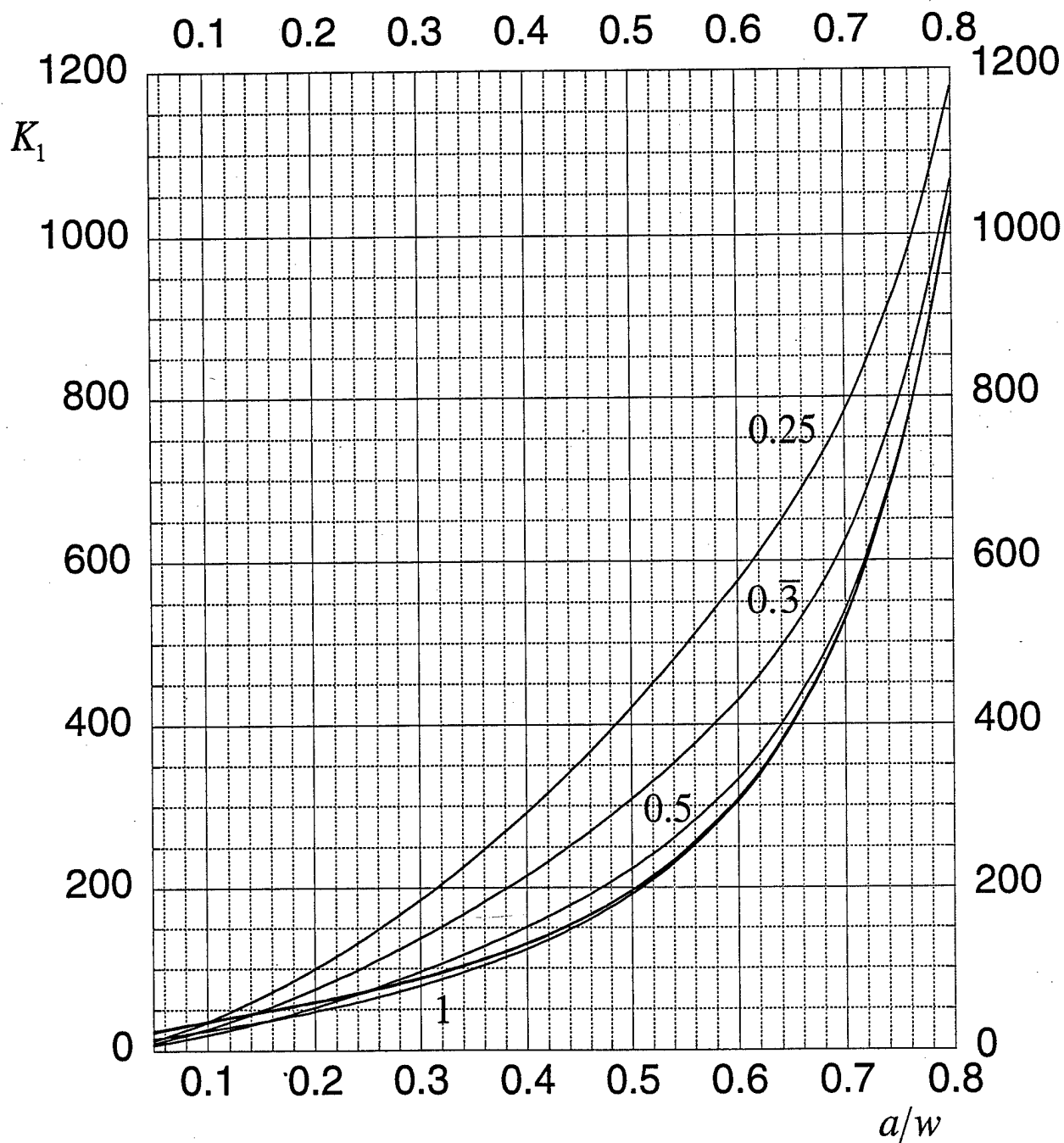
Biaxiality.
Applied uniform load.
Plane stress.

Normalized T-stress.
Applied uniform load.
Plane stress.
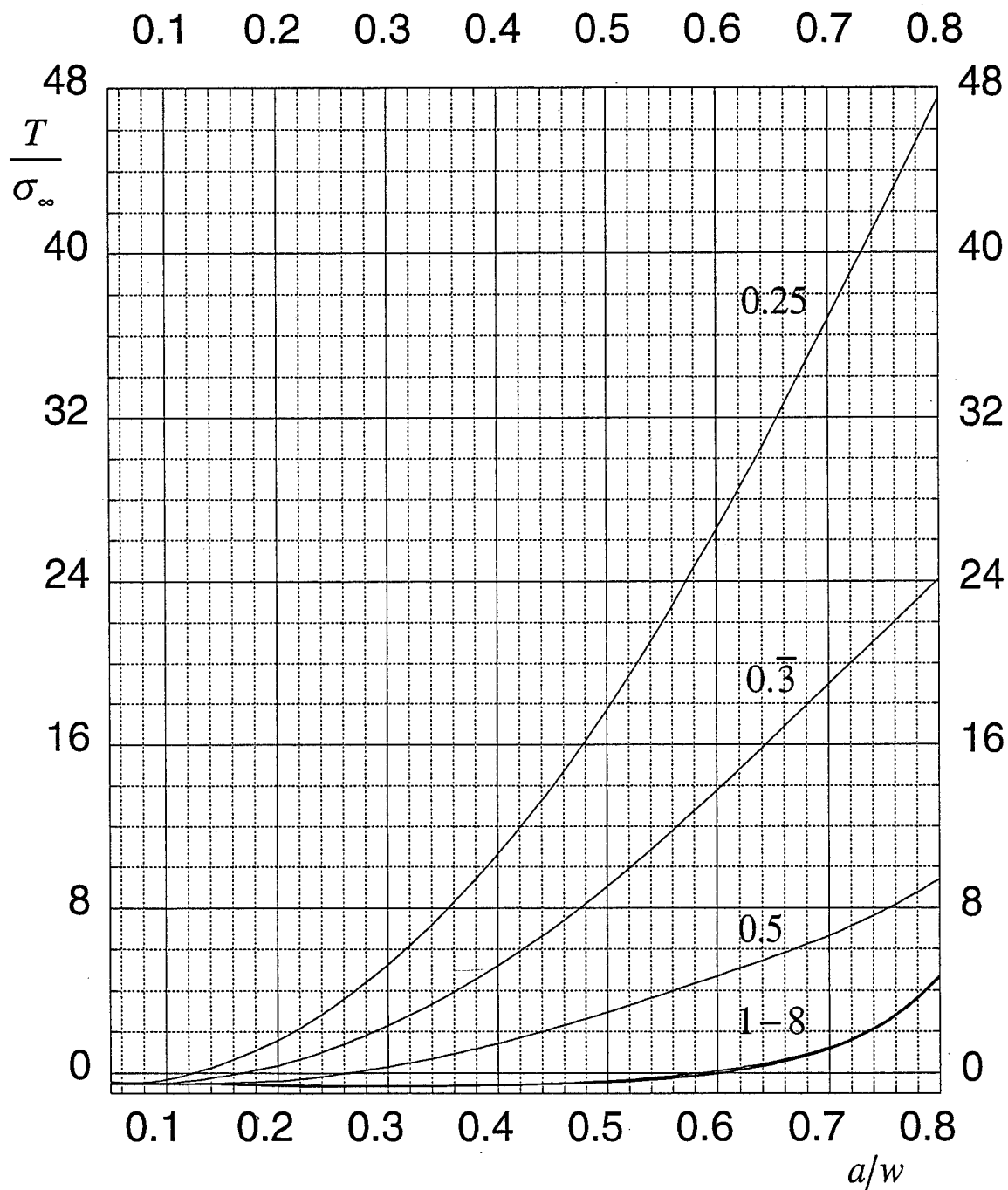
End stress.
Applied uniform load.
Plane stress.
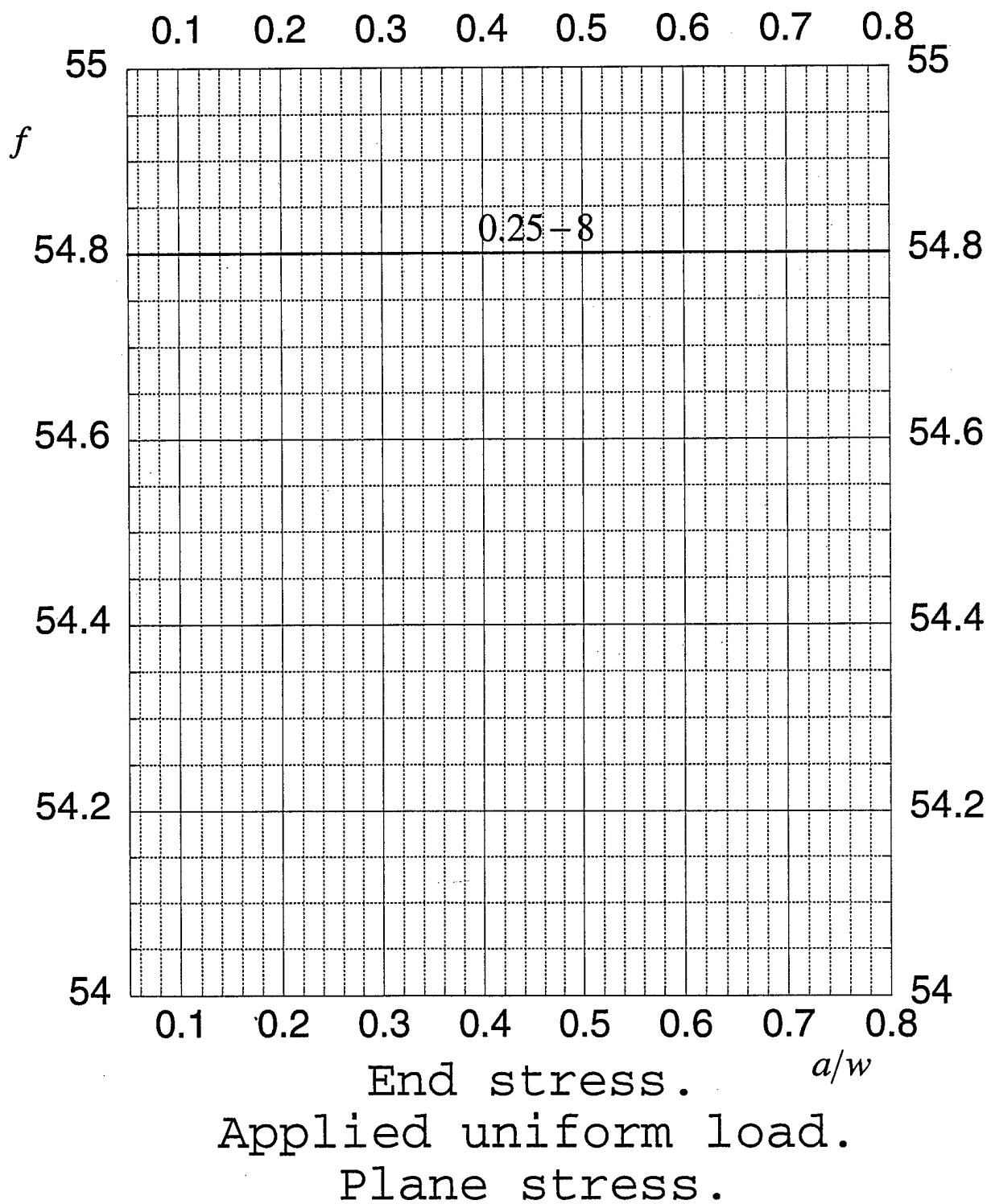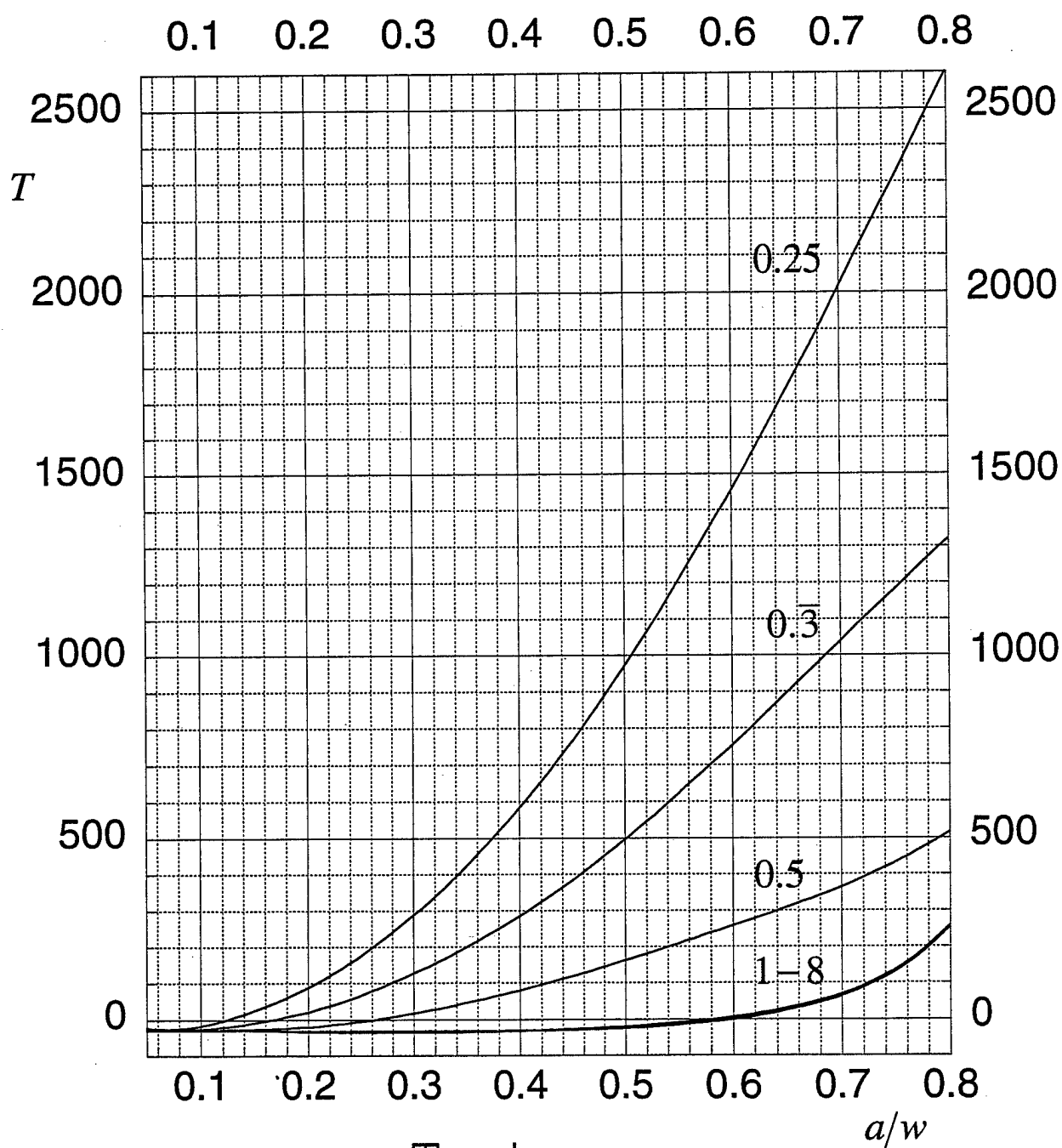
T-stress.
Applied uniform load.
Plane stress.
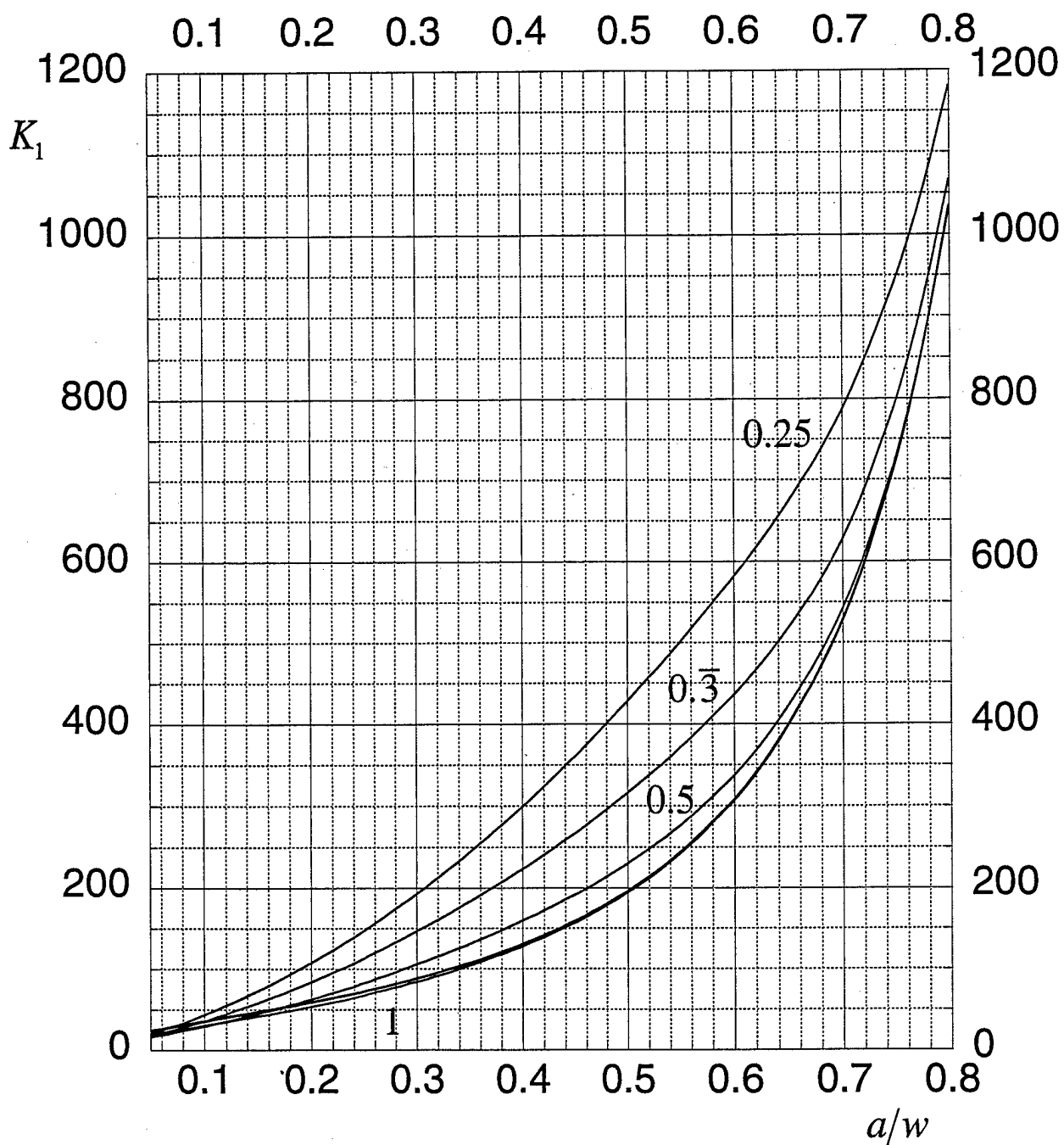
Stress intensity factor.
Applied uniform load.
Plane stress.
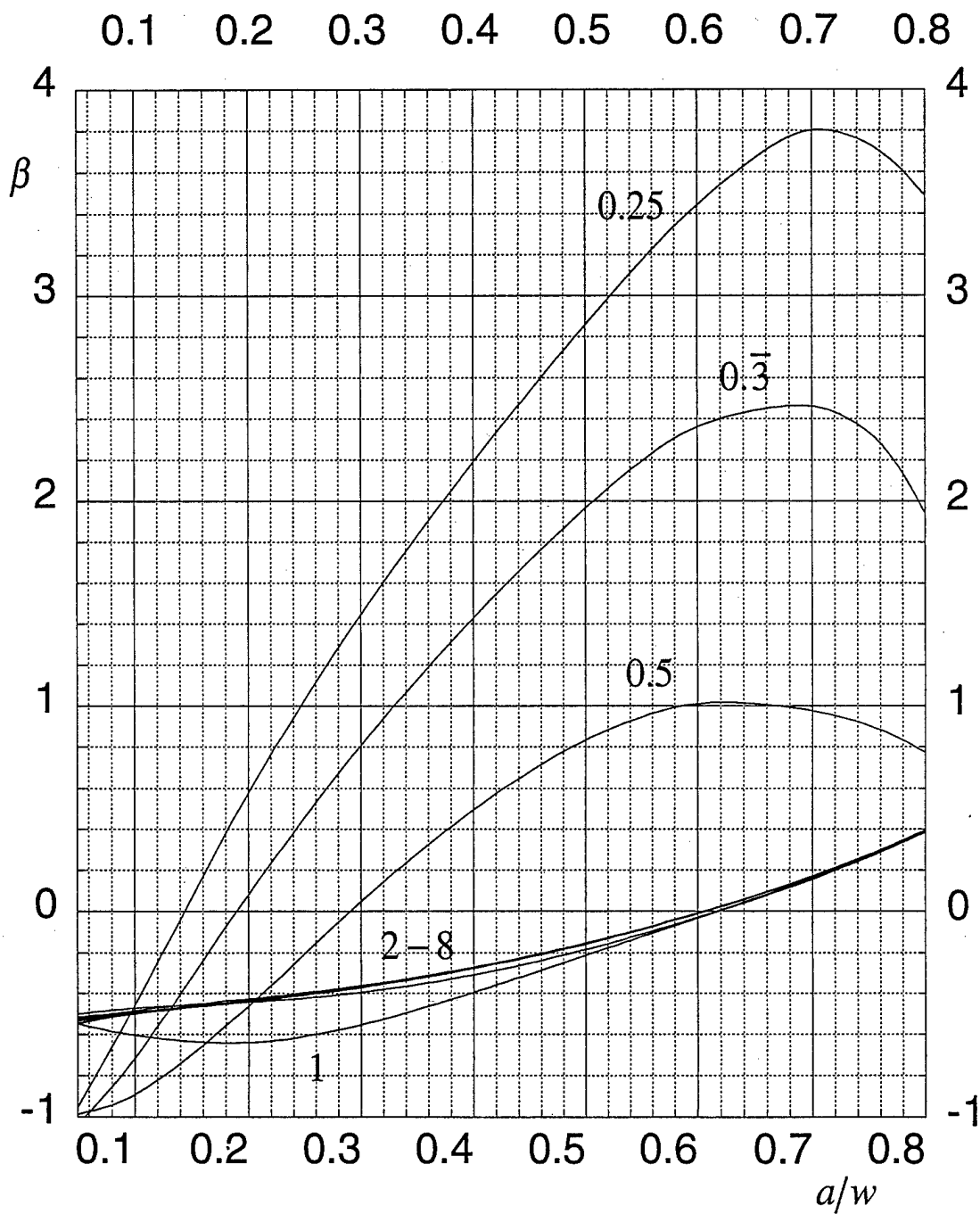
Biaxiality.
Applied uniform load.
Plane strain.
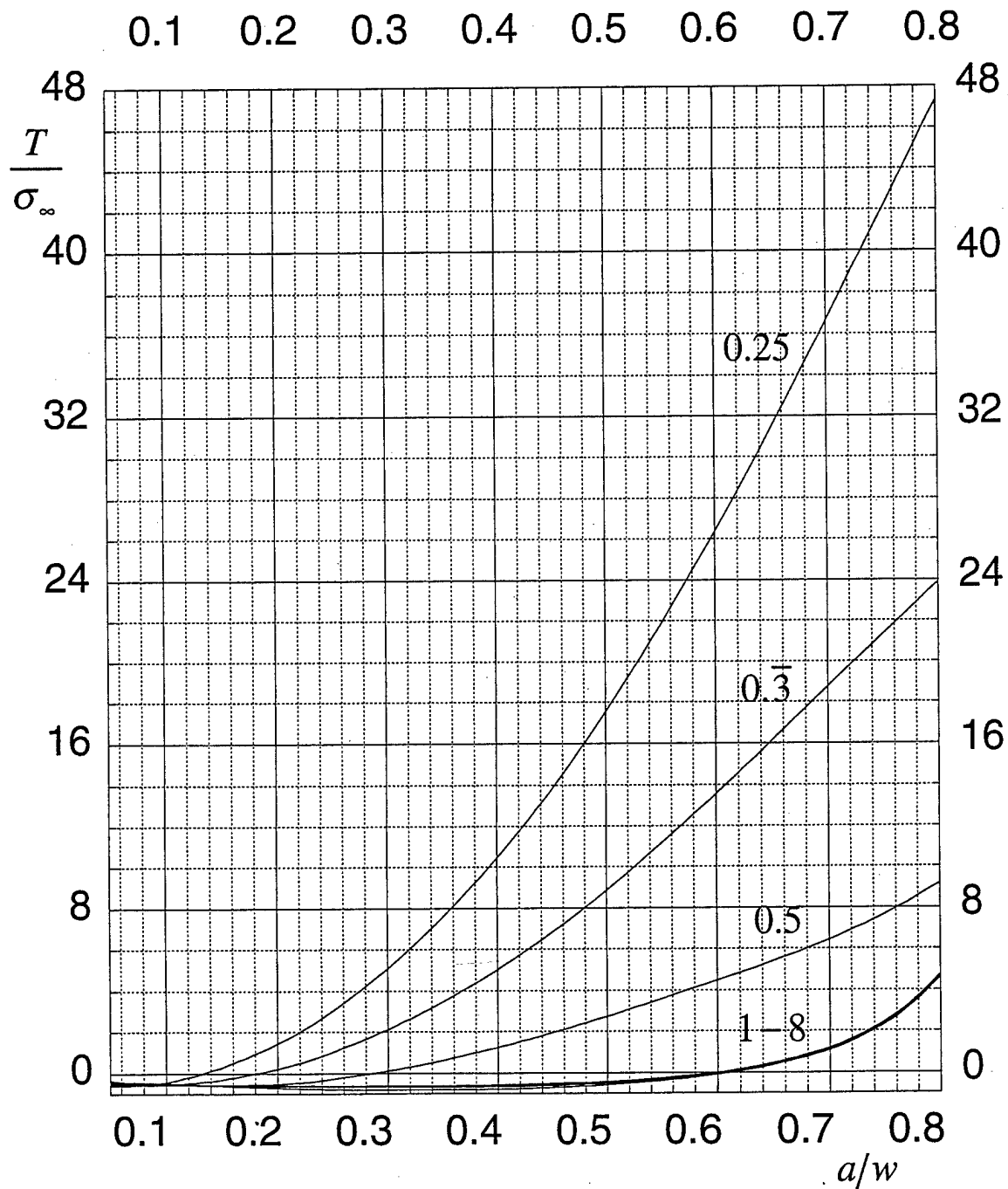
Normalized T-stress.
Applied uniform load.
Plane strain.
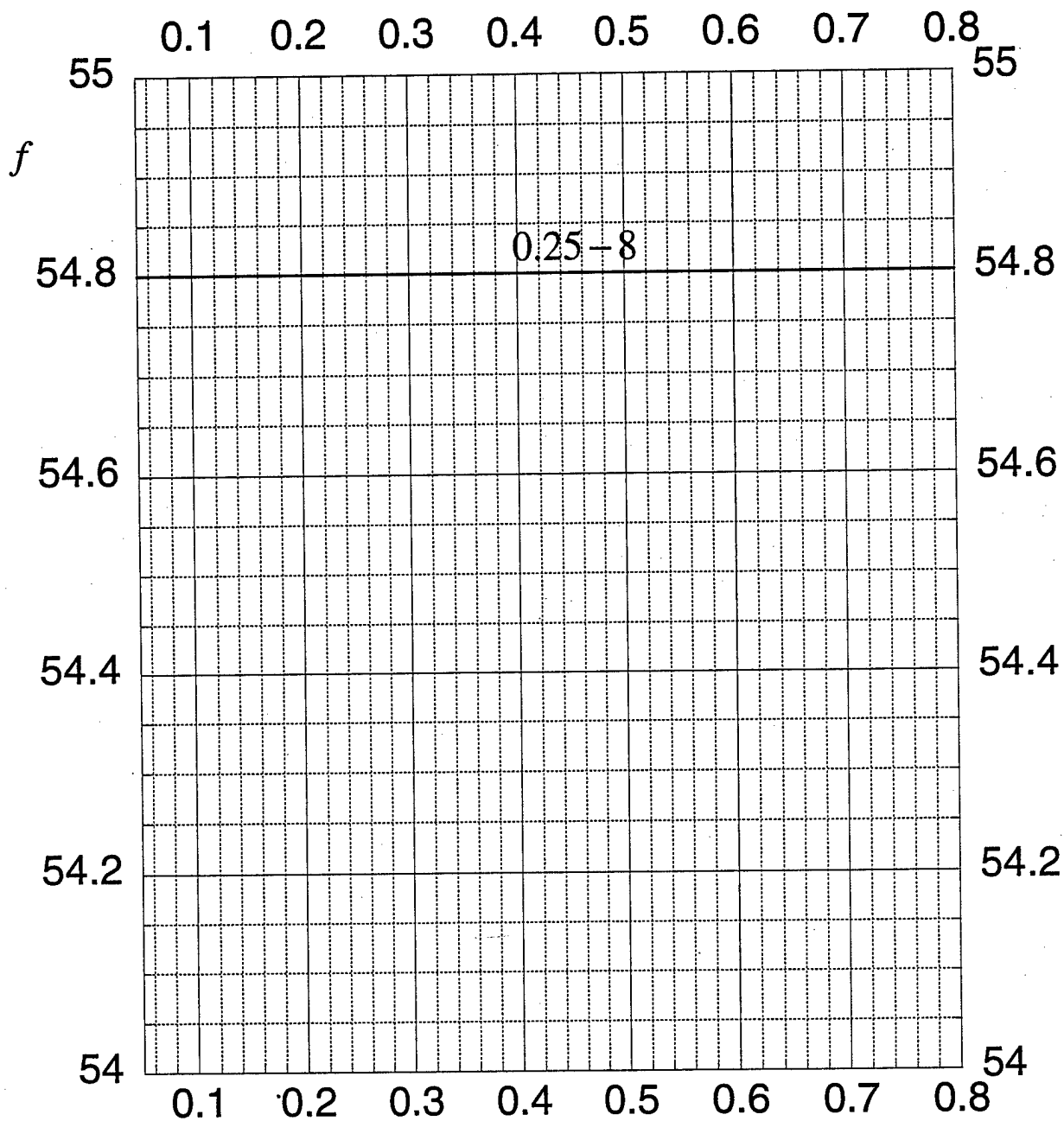
End stress.
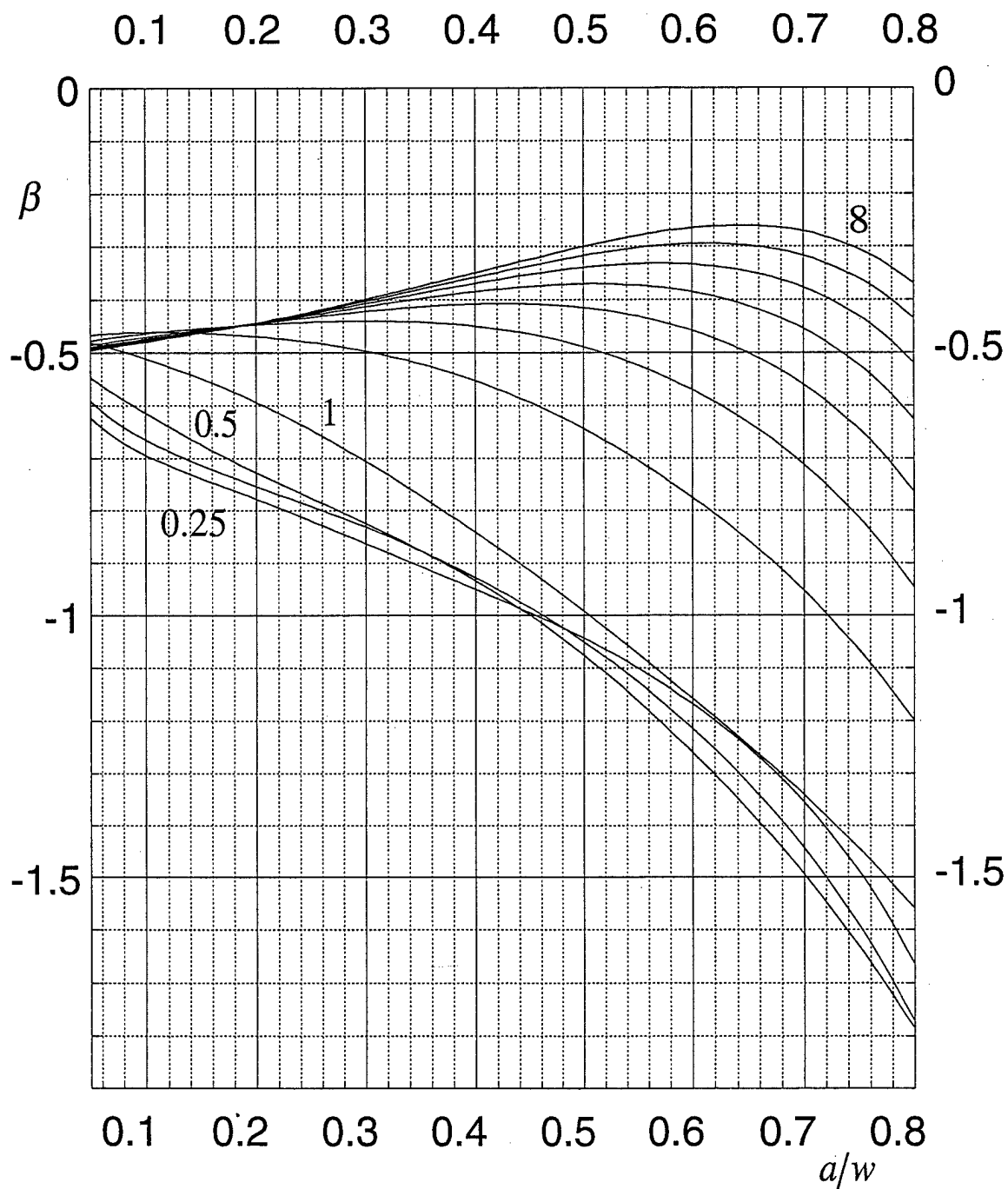Applied uniform load.
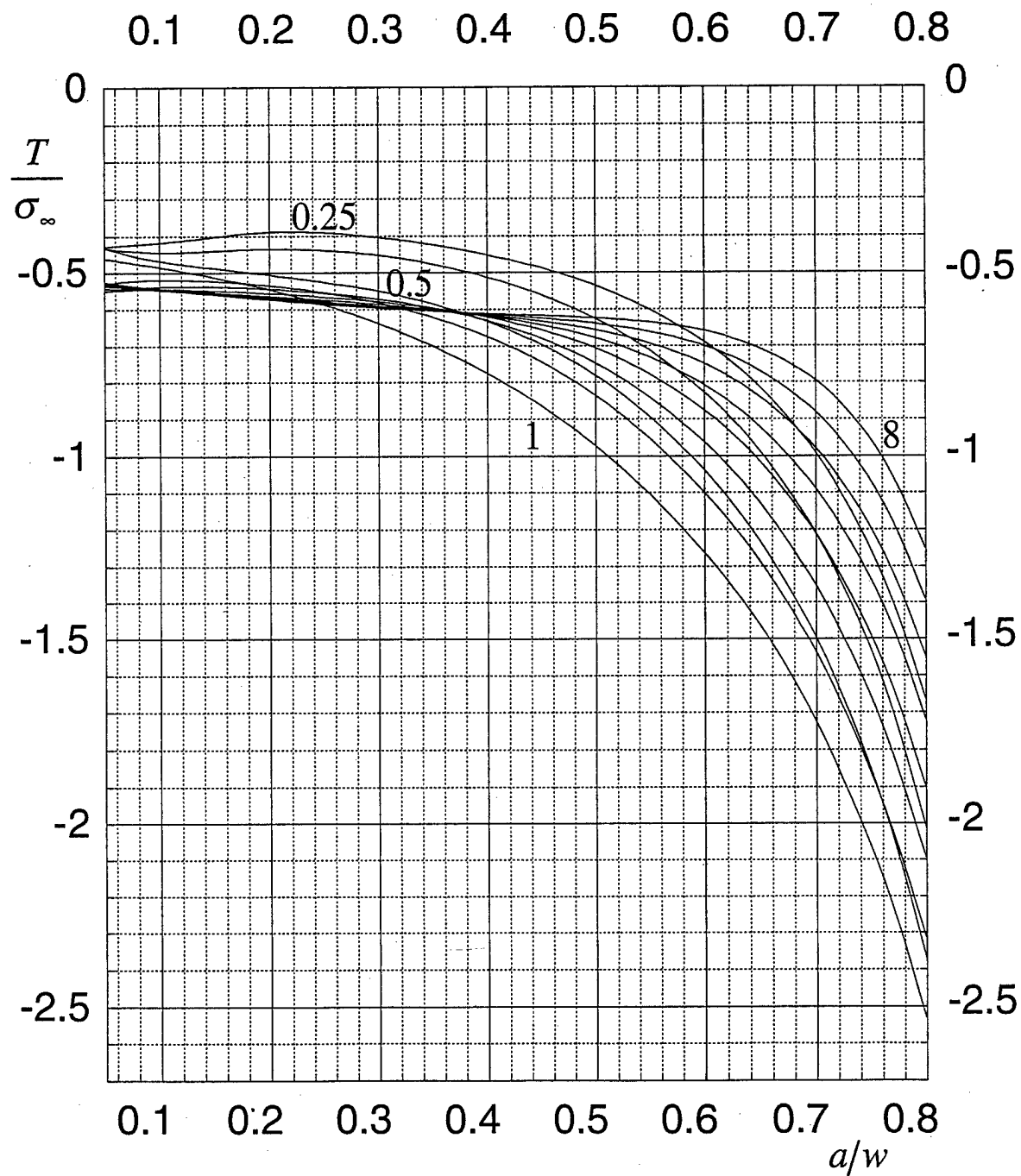Plane strain.
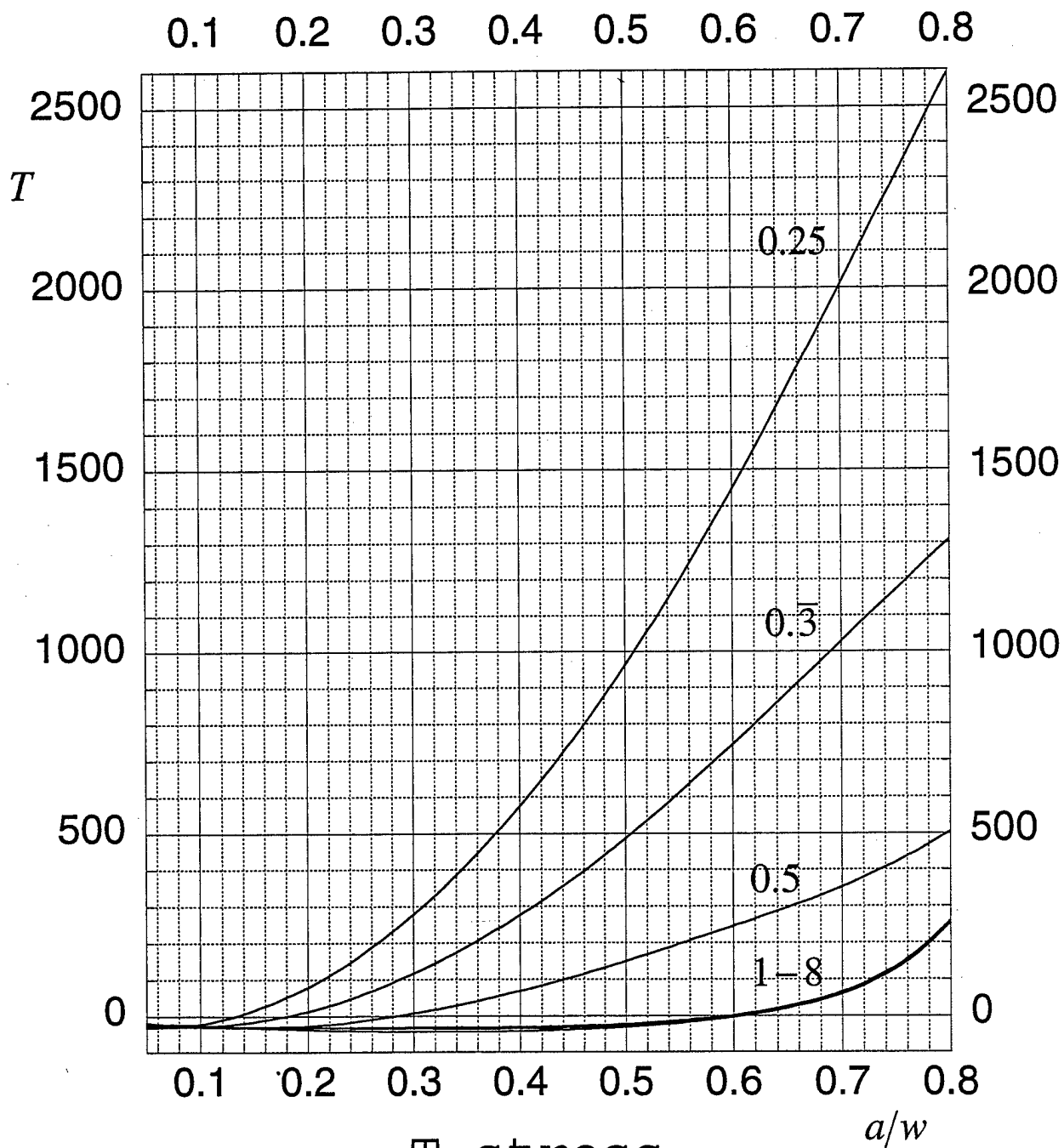
T-stress.
Applied uniform load.
Plane strain.

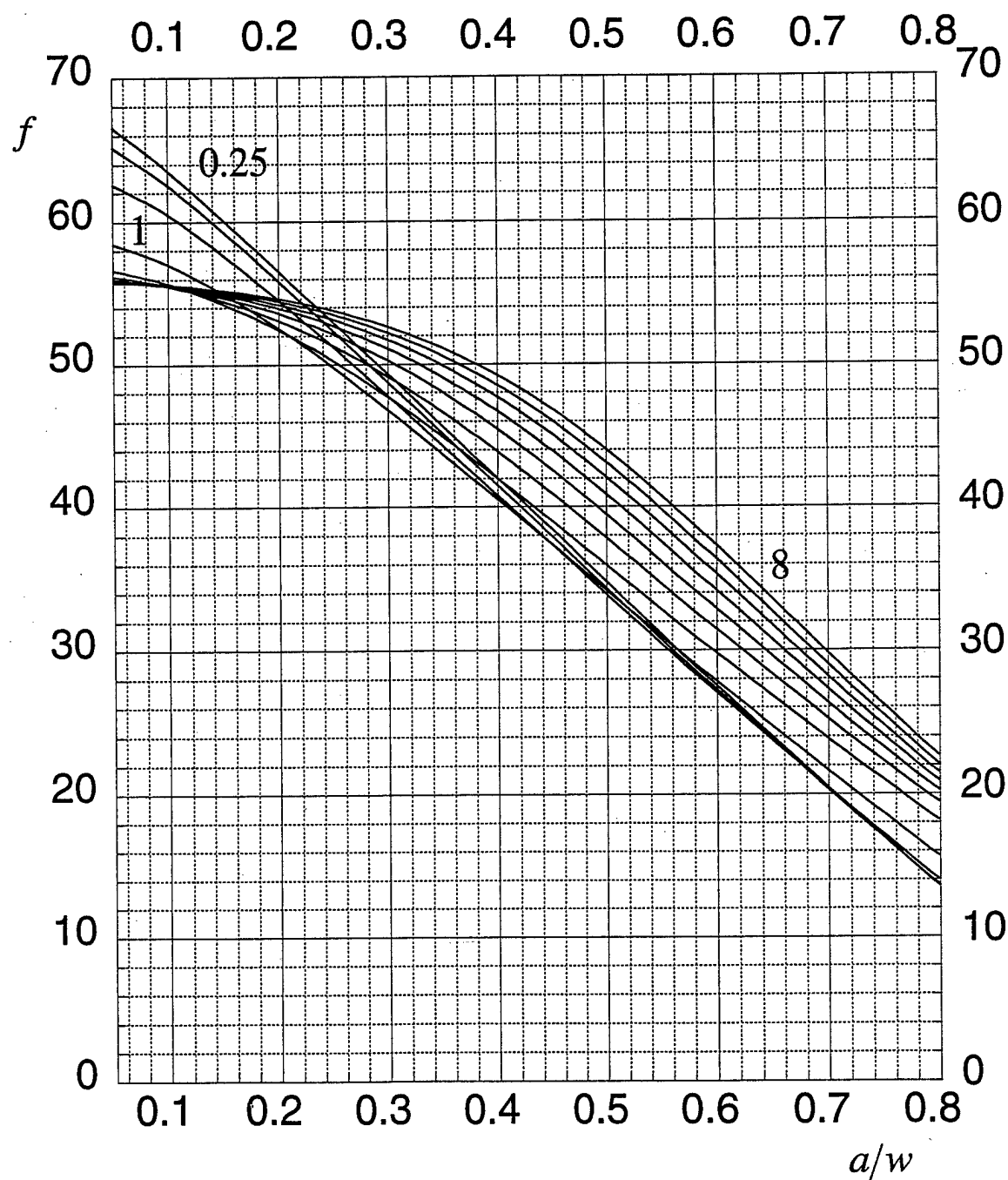Stress intensity factor.
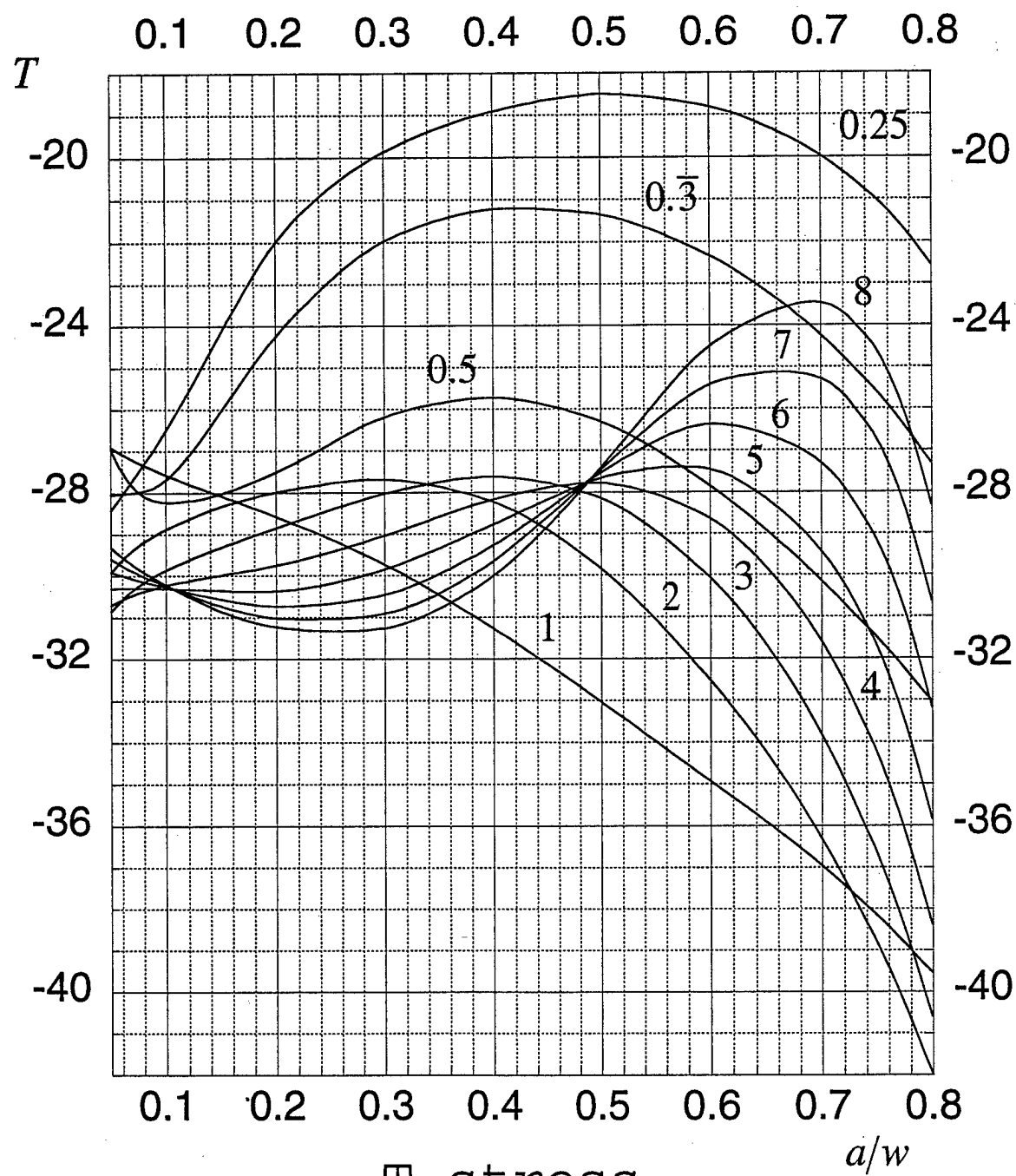Applied uniform load.
Plane strain.

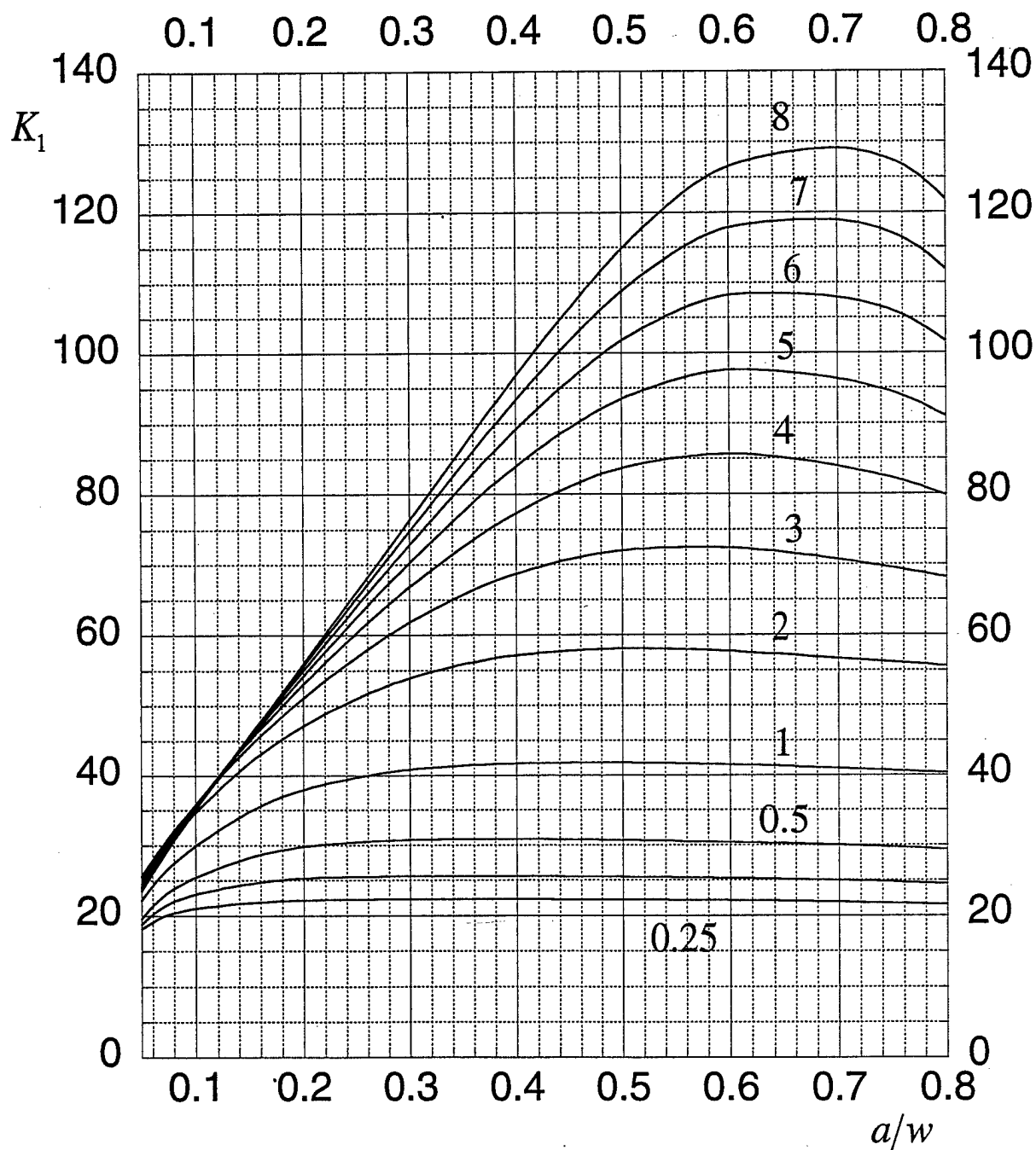Biaxiality.
Applied uniform displacement.
Plane stress.

Normalized T-stress.
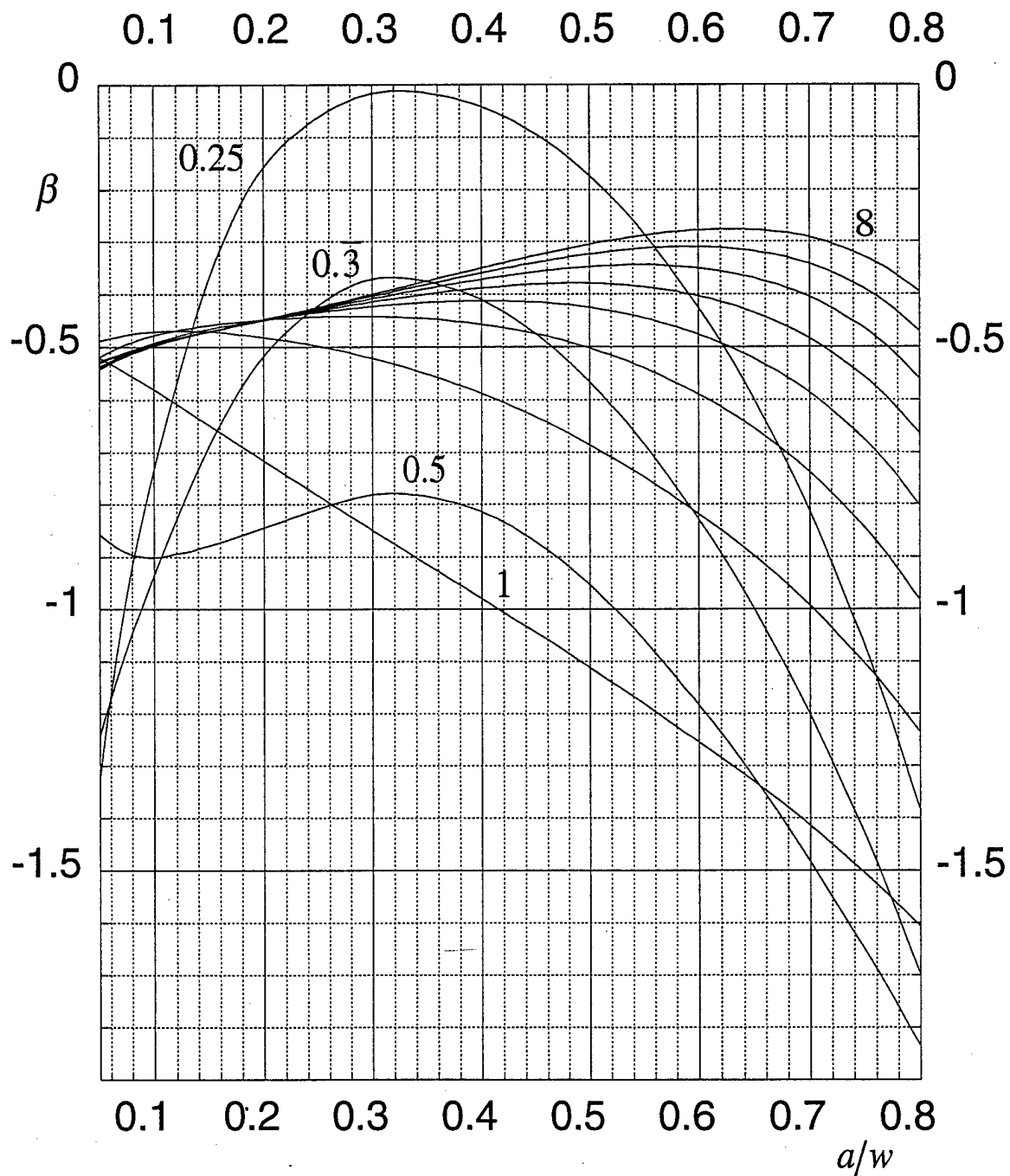Applied uniform displacement.
Plane stress.

Average induced end stress.
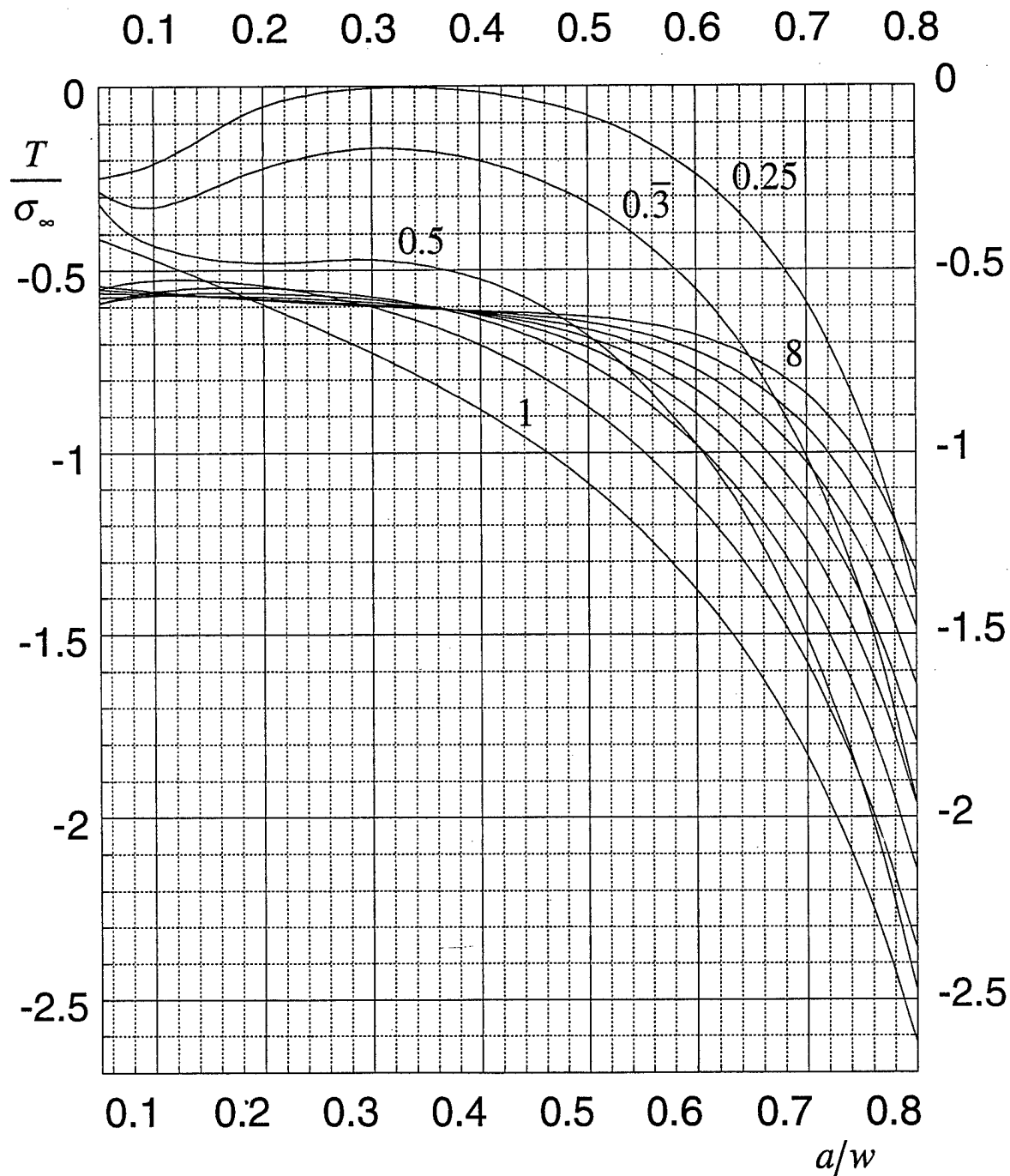Applied uniform displacement.
Plane stress.

T-stress.
Applied uniform displacement.
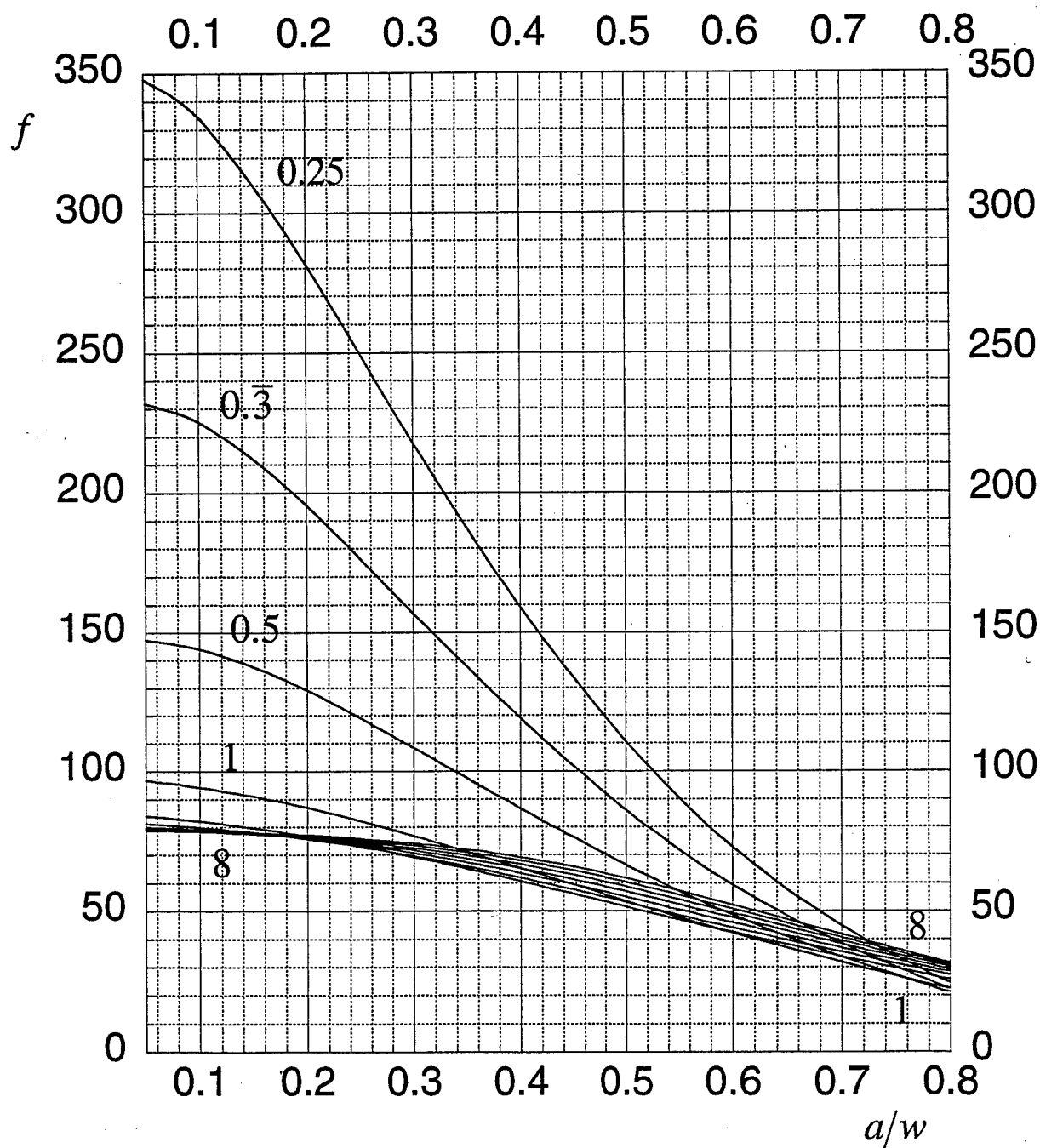Plane stress.

Stress intensity factor.
Applied uniform displacement.
Plane stress.

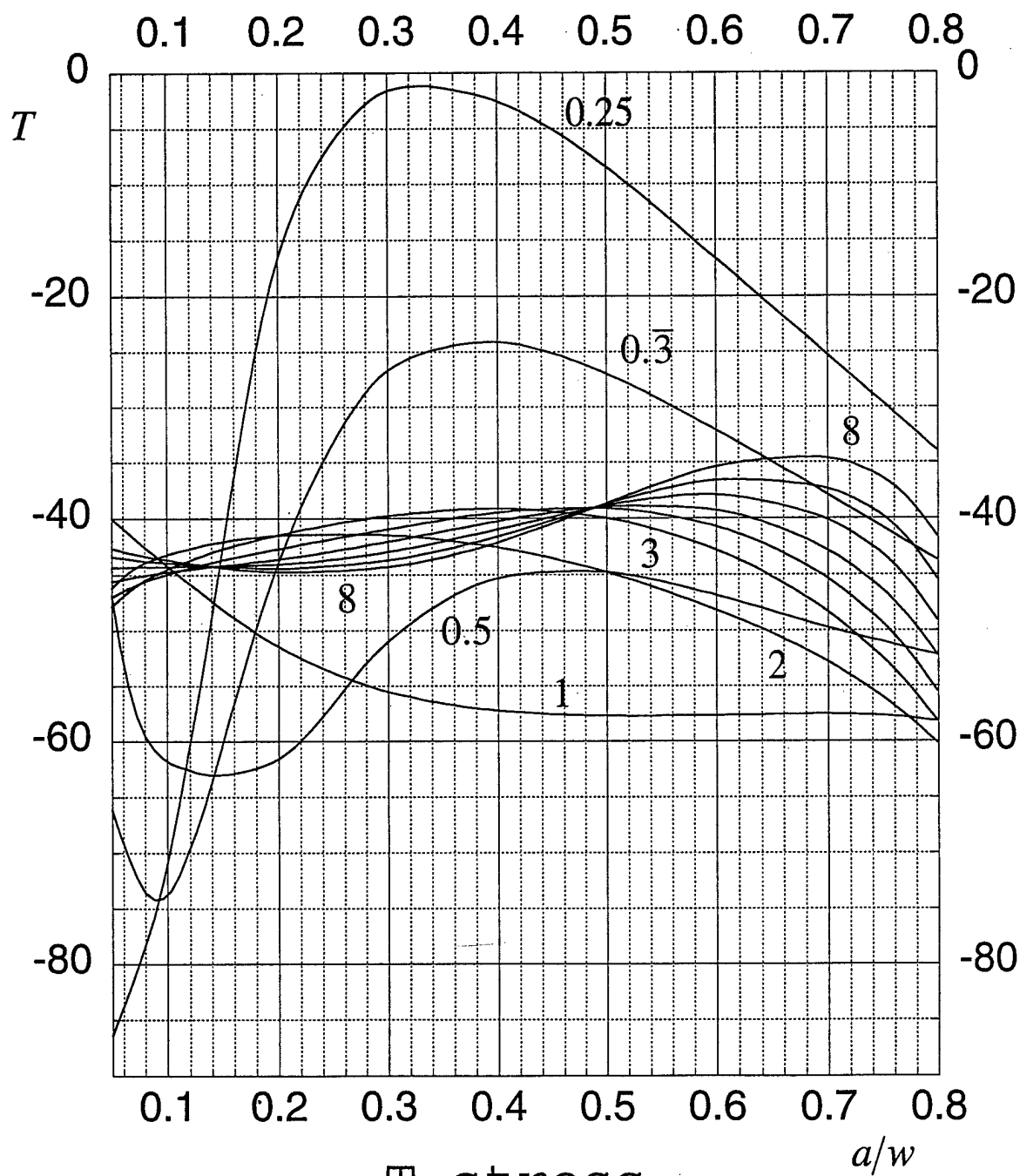Biaxiality.
Applied uniform displacement.
Plane strain.

Normalized T-stress.
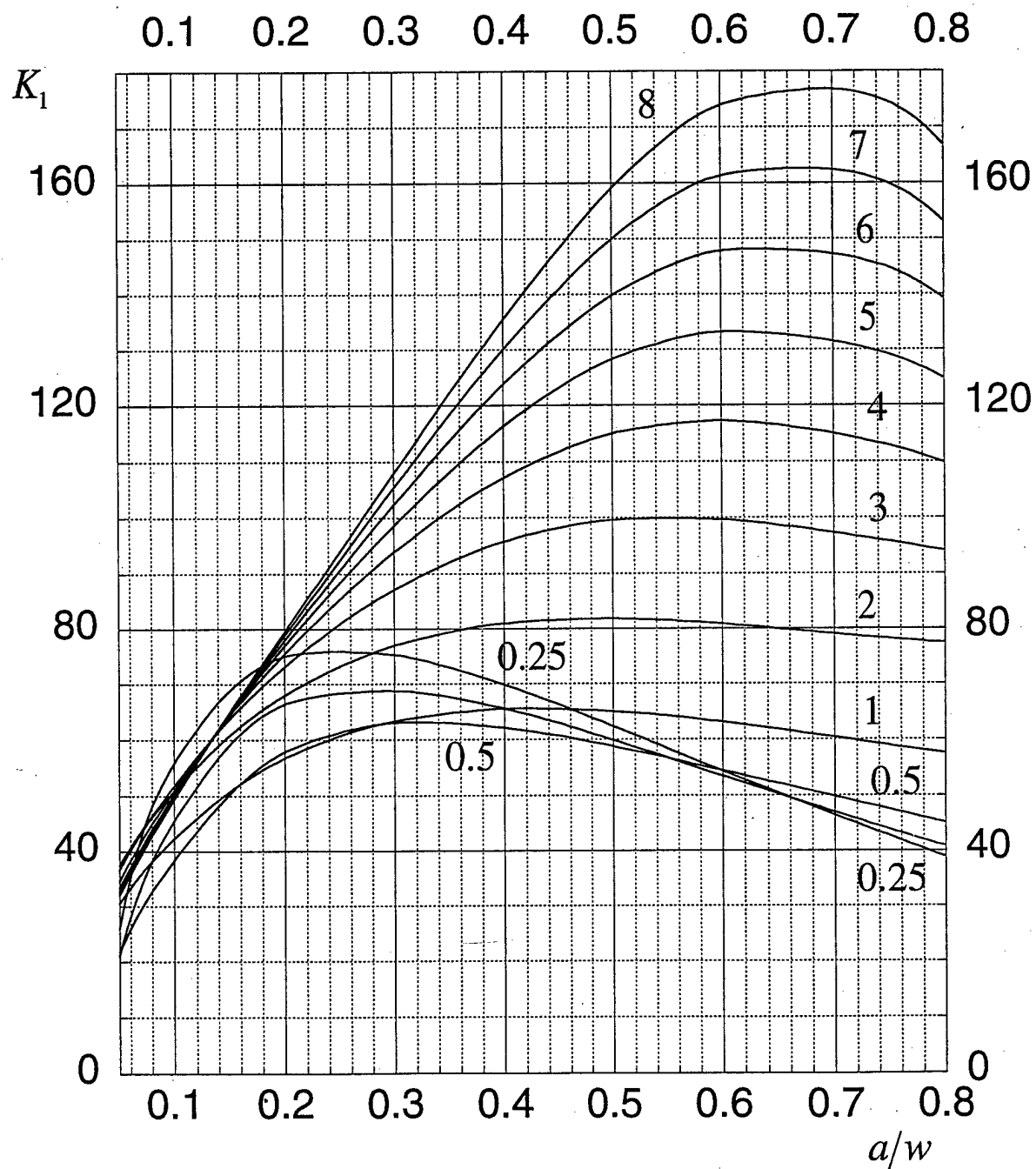Applied uniform displacement.
Plane strain.

Average induced end stress.
Applied uniform displacement.
Plane strain.

T-stress.
Applied uniform displacement.
Plane strain.

Stress intensity factor.
Applied uniform displacement.
Plane strain.

Conclusions

- The boundary condition in which the entire top edge of the mesh is constrained in the x direction was used, because it seems to be the one condition that can be practically implemented for an actual test specimen.

- For the case of applied uniform load, the effect of the particular plane state (stress or strain) on the values of K_1 and T is not significant.

- For the case of applied uniform displacement, the effect of the particular plane state (stress or strain) on the values of K_1 and T, is significant when the specimen aspect ratio (h/w) is less than one.

- The effect of whether applied uniform load or applied uniform displacement is used, is always extremely significant when calculating values for K_1 or T.

- Applying a load to a SENT specimen that is even approximately uniform is very difficult, unless the specimen is extremely long. Even if the end fixture is pinned at the middle, it only means that the centroid of the end load is thru the pin center.